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ABSTRACT

A longitudinal study examined the development of decoding skills, reading comprehension skills, and spelling skills across the first three years of primary education in order to examine the relations among the variables in a dynamic causal model of the development of reading and spelling skills. Subjects, 310 first grade children in 12 schools representing a random cluster sample falling to 225 subjects by the end of the third grade, were administered a variety of survey instruments during their primary education. The LISREL program was used to analyze thermany indices of global and local model fit and to help decide which of a number of models is the most reasonable. The data do not refute the hypothesis that decoding skills, reading comprehension, and spelling skills are empirically distinguishable latent variables. (Two tables and three figures of data are included; 20 references are attached.) (RS)

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MODELING, PREDICTING, AND MONITORING READING AND SPELLING ACHIEVEMENT

Martin Mommers & Johan Oud

Paper presented at 1st European Congress of Psychology, Amsterdam Holland, july 2-7, 1989

1.Introduction

Children entering primary school are faced with the task of achieving literacy. The literacy revolution (Chall, 1983) brought about by the tremendous increase in the amount of knowledge and the efficiency of the media in conveying knowledge, requires a higher level of literacy among more people than ever before.

It is well-known that a growing number of children has serious difficulties in grasping the alphabetic principle. In order to help these children learn to read and write, efficient and accurate means for assessing and predicting reading and spelling achievement at an early stage are needed. Developing such means, however, requires a precise model of the development of initial reading and spelling skills. Longitudinal studies spanning at least one or two years may help us model the process of reading and spelling. Cross-sectional studies may be useful too, but they are not suitable for unravelling the dynamic causal structure between relevant (sub)skills and assessing changes in this structure over time. In fact, the causal effects found in cross-sectional regression analyses often tend to be "explained away", when the lagged dependent variables are included in the equations as additional regressors (Oud, 1987).

In reading curricula, a distinction is usually made between decoding skills, spelling skills, and reading comprehension skills. In monitoring reading progress in children, it is important to know whether these types of skills can be identified as distinct (latent) variables during the course of literacy instruction and, if so, what the exact nature of their interrelations is. The link between decoding and reading comprehension has been the object of a number of investigations. Early efficient word recognition, for example, seems to lead to better comprehension rather than the other way around (Calfee & Piontkowski, 1981; Lesgold, Resnick & Hammond, 1985). With automatic word recognition, attention can be more fully focused on comprehension (LaBerge & Samuels, 1974). Perfetti and Lesgold (1979) assume that during the process of reading various subskills are competing for the limited capacity of the working memory. In experienced readers, the subprocesses at the level of word recognition largely operate automatically; they no longer tax processing capacity. Although for many children, automaticity in

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word processing skill seems to occur very early (by second or third grade), young readers have not yet fully developed automaticity of recognition. The extent to which these subprocesses call upon the working memory capacity constitutes an important source of individual differences between good and poor comprehenders. Moreover, if this is correct, the disparities in reading comprehension can largely be explained by the differences in word recognition speed or decoding skills. In other words, results such as those of Shanahan (1984) support the hypothesis that automatic lower level skills are critical to higher order cognitive processes.

With respect to the relation between decoding skills and spelling skills, it is assumed that they are distinguishable because the development of the pattern recognition mechanisms for identifying the visual features of words and spelling patterns is critical for reading (Reitsma, 1983) while spelling depends on the permanent storage of information regarding component letters and their sequence (Seymour & Porpodas, 1980). The fact that spelling skills often lag behind reading ability means that pattern recognition of words and parts of words does not imply storage of spelling structure in long term memory. It is conceivable, thus, that the decoding and spelling skills exert a mutual influence on each other (Stanovich, 1986).

The nature of the relationship between spelling and reading comprehension is far from clear at the moment. In the literature no obvious claims have been made about the causal relation of these two skills to each other.

In the present chapter an attempt is made to arrive at a computer aided assessment device for predicting and monitoring the development of reading and spelling skills in the initial stages of primary school. This is based upon a dynamic causal model. In order to carefully examine the relations among the various predictor variables in the model a longitudinal study was undertaken. In this study the development of decoding skills, reading comprehension skills, and spelling skills was followed across the first three years of primary education. The following model was postulated as a starting point.

Insert figure 1 here

The model assumes that decoding speed influences both reading comprehension and spelling. In addition, the latent variable of reading comprehension was assumed to influence spelling skills only. Moreover, it is expected that the strength of the causal relations between the latent variables will change during the development of reading. The model postulated is very simple and may be wrong. An advantage of starting with a simple model, however, is that the direction for modification in the case of a bad fit is usually clear. So it increases our understanding, a benefit that is not provided easily by complex models. In the following two sections the design and the results of the longitudinal study will be presented. In two additional sections, we will describe the two computer programs developed for

monitoring individual and group progress in reading and spelling skills. In a final section, the possibilities for modeling and predicting reading achievement will be discussed.

2. Design of the study

2.1 Subjects

A random cluster sample, consisting of 12 schools, was drawn. All children in the first grade of the selected schools participated, that is, at the start the total number of pupils was 310. At the end of the third grade, 225 pupils remained. The loss of subjects was attributable to moving, illness, repeating a class, and referral to special education.

2.2 Instruments

Although data have been gathered in grades 1, 2, 3, and 6, the present study covers only the first three years of the primary school. The measuring instruments shown in table 1 are restricted to these grades.

Insert here table 1

A short description of the instruments is as follows.

1. Matrices. This test resembles Raven's Progressive Matrices. It is a non-verbal test measuring general reasoning abilities.
2. Copying Forms. The child is asked to copy a figure by connecting the dots within a frame. This technique was designed for intelligence testing with young children.
3. Kindergarten Teacher Judgment. This is a five-point rating scale of the general learning readiness of the children by the kindergarten teacher.
4. Letter Cluster Identification. Each item asks the subject to choose a target cluster out of a a set of four alternatives.
5. Auditory Blending. The child has to combine the sounds of a word by choosing the picture representing this word from among five alternatives.
6. Auditory Segmentation. The child is asked to divide a spoken word into phonemes by choosing from three alternatives the picture representing the word that begins with the same sound as the stimulus word.
7. Caesar One-Minute Test. The score is the number of words in a list read correctly within one minute. This test measures decoding speed.
8, 13, 19, 26, and 32. AVI Reading Test. This test is designed to measure decoding speed by having the child read a little story.
9 and 14. Reading Comprehension. These tests were designed to measure three comprehension skills: vocabulary, sentence comprehension and intersentential relations.
10, 15, 22, 28 and 35. Spelling: words. Dictation tests consisting of single words.
11, 16, 17, 23, 24, 29, 30, 36, and 37. Spelling: sentences. Dictation tests consisting of 5 sentences each.

12, 18, 25, and 31. Brus and Voeten's One-Minute Test. This test is comparable to the Caesar One-Minute Test.

20 and 34. Reading Comprehension. These tests were designed to measure sentence comprehension and comprehension of intersentential relations.

21, 27 and 33. Written Assignments. These reading comprehension tests were designed to measure understanding of short written assignments.

Further details about the instruments can be found in Mommers (1987) and in Mommers et al. (1986).

2.3 Procedure

In figure 1 an attempt is made to construct a causal model based on what is known in the literature about the relation between decoding skills, reading comprehension, and spelling skills. Because of lack of knowledge, it is not possible to specify the model as the definitive one. An analytic procedure that can tell us which of a number of models is the most reasonable one was adopted. The LISREL program gives many indices of global and local model fit and of fit improvement. It therefore informs the analyst about the directions that any modification should take. An attractive feature of the LISREL approach is, moreover, the distinction made between latent and observed variables. This offers the possibility of keeping the latent causal structure rather simple (principle of parsimony), while linking the observed variables in a reliable and valid way to the latent variables. The main reasons for using the LISREL method were (a) it allows models that combine cross-sectional instantaneous effects with longitudinal dynamic effects to be analyzed, (b) both observed and latent variables can be included in the model, and (c) the LISREL program offers the possibility to evaluate the global model fit (GFI: goodness of fit index) as well the local model fit (MM: model modifications indices).

3. Modeling the acquisition of reading

3.1 Relationships among latent variables

Insert figure 2 here

All of the steps involved in the construction of a fairly good fitting model cannot be described here. The reader is referred to Mommers et al. (1986) for a detailed description. To make a long story short, figure 2 shows one of the best models. The goodness of fit index (GFI) for this model is .829 and the adjusted goodness of fit index (AGFI) is .792. In order to understand the model a few points should be made.

In the path diagram of figure 2 observed variables are enclosed in squares and latent variables are enclosed in circles. Each standardized path coefficient indicates the strength of the influence of a variable taken as a cause on a variable taken as an effect. To prevent the figure from becoming too complicated, the Reading Comprehension (RC) factors have been repeated at the top

of the figure. Here, the effects of the Prerequisites (P) factor on the consecutive RC factors are indicated with arrows and path coefficients. The observed variables 8, 13, 19, 26, and 32 are connected both with the Decoding Speed (DS) factors and the RC factors. Initially it was assumed that the AVI test would load only on the DS factors. However, the results indicated a much better fit, when this variable was also allowed to load on the RC factors.

3.2 Results

The data do not reject the hypothesis that decoding skills, reading comprehension and spelling skills are empirically distinguishable latent variables. The effects over time of the latent variables on themselves are high, while their effects on each other proved to be rather low. The path-coefficients for the latent variable Decoding Speed at different points in time are all above .900. The path coefficients for Spelling (SP) are somewhat lower than those for Decoding Speed, but the lowest coefficient is still .700 and the highest one is not less than .839. This suggests that Decoding Speed and Spelling remain rather stable latent variables during the first three years of elementary school. In contrast, the path-coefficients concerning Reading Comprehension at different points in time were relatively much lower (see, especially, the values .443 and .327 at times 1 and 2, respectively). This is conceivably due to the different types of tests used at different points in time. It is also reasonable to assume that achievements in reading comprehension during the lower grades do not depend on the same mental abilities as is the case in higher grades. The substantial direct effects of Prerequisites on Reading Comprehensionn (RC2, RC3, and RC4) were not expected and may be an indication that earlier conceptual knowledge plays a part in reading comprehension at later stages as well.

Up to and including the beginning of grade three a positive effect of Decoding Speed on Reading Comprehension exists. The same is true for the influence of Reading Comprehension on Spelling. At all points in time, positive coefficients are found for the influence of Decoding Speed on Spelling. The coefficients lower than .19 are not significant, however.

The relation between Reading Comprehension and Spelling is not clearly motivated from a theoretical point of view. An analysis in which the direction of the arrows between the Reading Comprehension factor and the Spelling factor were reversed was therefore undertaken. The fit of this alternative model proved to be less acceptable, however.

3.3 Predictive value of the model.

The LISREL program provides squared multiple correlations for the structural equations. Table 2 shows these squared correlations which indicate the percentage of variance accounted for in the model.

Insert here table 2

At the fourth and fifth measurement points more than 90% of the variance in Decoding Speed and Reading Comprehension is accounted for, at each measurement point more than 80% of the Spelling variance is accounted for. These high percentages suggest that the model may be very suitable for use in a monitoring system of reading progress.

In the introduction to this paper it was noted that causal effects found in cross-sectional regression analyses often tend to disappear in longitudinal analyses. For this reason, the data of the fourth measurement point were analyzed separately. A significant effect was found in this cross-sectional analysis for Decoding Speed on Reading Comprehension (path coefficient .646) and for Decoding Speed on Spelling (path coefficent .759). In comparison, the corresponding path coefficients from the longitudinal analysis in figure 2 turn out to be dramatically lower. This illustrates that cross-sectional analysis may provide a distorted picture of the causal processes underlying reading development, and that longitudinal research is indispensable in studying such processes.

4. Predicting reading achievement

4.1 Monitoring individual progress

For early detection of learning and social developmental problems in primary school children, effective monitoring methods are needed. The computer program LISKAL has recently been constructed for this purpose. LISKAL is available in two versions, a general main frame version and a personal computer version. The latter version is specially designed to assess the development of reading and spelling skills on the basis of the model presented in figure 2.

Assessment of latent developmental curves for individual subjects is performed in the LISKAL program using the Kalman-filter. The Kalman-filter originates from control theory and is known to be optimal in estimating current latent values on the basis of current as well as past values of observed variables. The Kalman filter is, in fact, the optimal factor score estimator for use with longitudinal data (Oud, Van den Bercken, & Essers, 1986)

Insert here figure 3

The upper part of figure 3 shows for a particular pupil the development of Decoding Speed and Reading Comprehension as generated by LISKAL for a particular pupil. Development is described in terms of z-scores; that is, relative to the mean developmental curve and in terms of the standard deviations of the reference group on which the LISREL model is based. This pupil's Decoding Speed turns out to be lower than the mean of the reference group. At the first four points of measurement Reading Comprehension is above the mean. However, from the second point onwards the level decreases and at the fifth point the z-score is

about zero.

In addition to current latent values, the LISKAL program also computes predicted future values on the basis of the LISREL model. In the lower part of figure 3 the values predicted on the basis of the first measurement are presented. Comparing the upper and the lower part of figure 3 makes clear that for Reading Comprehension the prediction is more favourable than the level that has actually been reached.

The effectiveness of LISKAL as a developmental monitoring method is enhanced by several features. First, normative assessment of individual subjects in terms of the reference group is made possible by standardizing the LISREL model for this group. Second, relative improvement or deterioration of the subject's position relative to the reference group can be assessed by comparing successive Kalman filter estimates. Third, the LISREL model can be used to predict future development of the subject relative to the reference group. Significant expected deterioration may be a reason to initiate intervention activities for improvement. Fourth, intervention effects may be evaluated by comparing the actual development with the predicted (expected) development without intervention. Fifth, in case of missing values at one or more measurement points (due to, for example, illness), LISKAL subtitutes predicted values for actual ones and keeps being optimal for the information available.

4.2 Monitoring group progress

In many situations, teachers are not only interested in the development of individual pupils but also want to analyze the progress of groups of pupils as a whole. For example, teachers may want to evaluate teaching results on the class level or compare different classes. The individual developmental curves produced by the LISKAL program may be collected and analyzed on the group level by means of a second computer program: TIDA (Oud, Reelick, & Raaijmakers, 1986). This progam is available only in a general main frame version. Just as LISKAL, this program gives the main results in graphic form. The crucial difference is thatLISKAL generates developmental curves for individual subjects, while TIDA analyzes developmental curves for groups.

TIDA uses MANOVA for the statistical analysis of time-series data and is specially designed to analyze intervention effects on the group level. It provides graphic tests for many kinds of important developmental and intervention hypotheses. Examples of questions which might be answered by TIDA are the following. Is the mean class curve significantly different from the mean reference group curve? Does the mean class curve improve significantly over time? Is there a significant change in the mean class curve at the intervention point? At which points does the mean curve of class A significantly differ from the mean curve of class B? Does a significant difference exist between the curves of two groups after any initial differences have been eliminated?

5. Conclusions and discussion

In recent years there have been a number of attempts to

design models of the reading process and learning to read (Singer & Ruddel, 1976). Some models have to a certain extent been empirically validated (Curtis, 1980; Butler et al., 1985; Juel et al. 1986). However, in only a few instances (e.g., in the interesting study by Frederiksen, 1982) the LISREL approach is used. Most authors break up reading into components or subskills in order to gain more insight into the complex reading process and its development over time. According to them, it is essential to specify the relevant subskills very accurately and, when possible, operationalize them with very specific tasks. Most of the tests in the present study are too complex to distinguish such components. This difficulty has partly been solved, however, by defining the relevant components as the factors on which the particular tests load. Nevertheless, the LISREL model presented here is not perfect. Although it may be improved upon, it derives its value from the interplay between theory and empirical data. Further testing of the model among other populations and under different circumstances is called for in order to justify generalizations.

Writing is the basic tool of literacy. An analysis of learning to read shows that a universal task in all languages is to learn <u>how</u> the writing system represents language. But this process varies from one language to another. The Dutch orthographic system is much more regular than the English and the French ones, for example. It will therefore be interesting to gather comparable data for different language systems and compare the results. The results will be useful for the planning of course material, the formulation of objectives, and the diagnosis of reading and spelling difficulties. Pupils with reading and spelling difficulties may deviate from the normal pattern in many ways. Using the above analyses, developmental discrepancies in the relevant reading skills of Decoding Speed, Reading Comprehension, and Spelling can be identified and are to be examined in individual cases. In any integrated course for formal reading instruction, of course, detailed attention will have to be paid to the development of Decoding Speed, Reading Comprehension, and Spelling.

Table 1: Data gathering instruments at six points of measurement. The corresponding factors are shown in brackets. P is Prerequisites, DS is Decoding Speed, RC is Reading Comprehension and SP is spelling.

Time 0: Before the beginning of formal reading instruction	
1. Matrices	(P)
2. Copying forms	(P)
3. Rating Kindergarten teacher	(P)
4. Letter cluster identification	(P)
5. Auditory blending test	(P)
6. Auditory segmentation test	(P)
Time 1: After a 9-month period of reading instruction	
7. Caesar One Minute test (seperate words)	(DS1)
8. AVI reading speed test (paragraphs)	(DS1+RC1)
9. Reading comprehension 1A	(RC1)
10. Spelling, words 2	(SP1)
11. Spelling, sentences B1	(SP1)
Time 2: After a 14-month period of reading instruction	
12. Brus-Voeten One Minute Test (seperate words)	(DS2)
13. AVI reading speed test (paragraphs)	(DS2+RC2)
14. Reading comprehension 1B	(RC2)
15. Spelling, words OBCE-1	(SP2)
16. Spelling, sentences B2	(SP2)
17. Spelling, sentences C1	(SP2)
Time 3: After a 19-month period of reading instruction	
18. Brus-Voeten One Minute Test (seperate words)	(DS3)
19. AVI reading speed test (paragraphs)	(DS3+RC3)
20. Reading comprehension 2 (Cito)	(RC3)
21. Written assignments 2	(RC3)
22. Spelling, words OBCE-2	(SP3)
23. Spelling, sentences C2	(SP3)
24. Spelling, sentences D1	(SP3)
Time 4: After a 26-month period of reading instruction	
25. Brus-Voeten One Minute Test (seperate words)	(DS4)
26. AVI reading speed test (paragraphs)	(DS4+RC4)
27. Written assignments 3	(RC4)
28. Spelling, words OBCE-2	(SP4)
29. Spelling, sentences D2	(SP4)
30. Spelling, sentences E1	(SP4)
Time 5: After a 31-month period of reading instruction	
31. Brus-Voeten One Minute Test (seperate words)	(DS5)
32. AVI reading speed test (paragraphs)	(DS5+RC5)
33. Written assignments 4	(RC5)
34. Reading comprehension M3 (Cito)	(RC5)
35. Spelling, words OBCE-3	(SP5)
36. Spelling, sentences E2	(SP5)
37. Spelling, sentences F1	(SP5)

Table 2: Squared multiple correlations for structural equations

DS1	.414	DS2	.859	DS3	.818
RC1	.541	RC2	.624	RC3	.720
SP1	.569	SP2	.829	SP3	.805
DS4	.920	DS5	.935		
RC4	.917	RC5	.906		
SP4	.814	SP5	.831		

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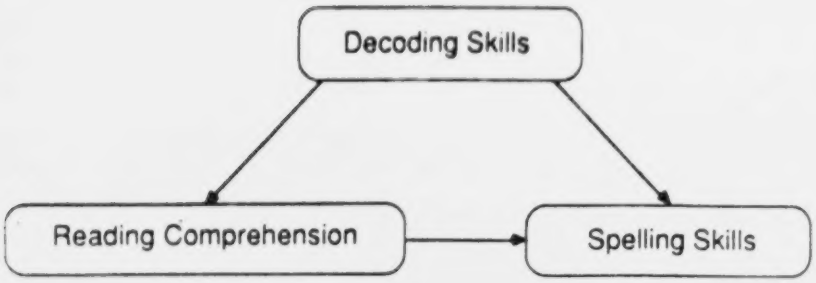

Figure 1
The model postulated as a starting point for analysis

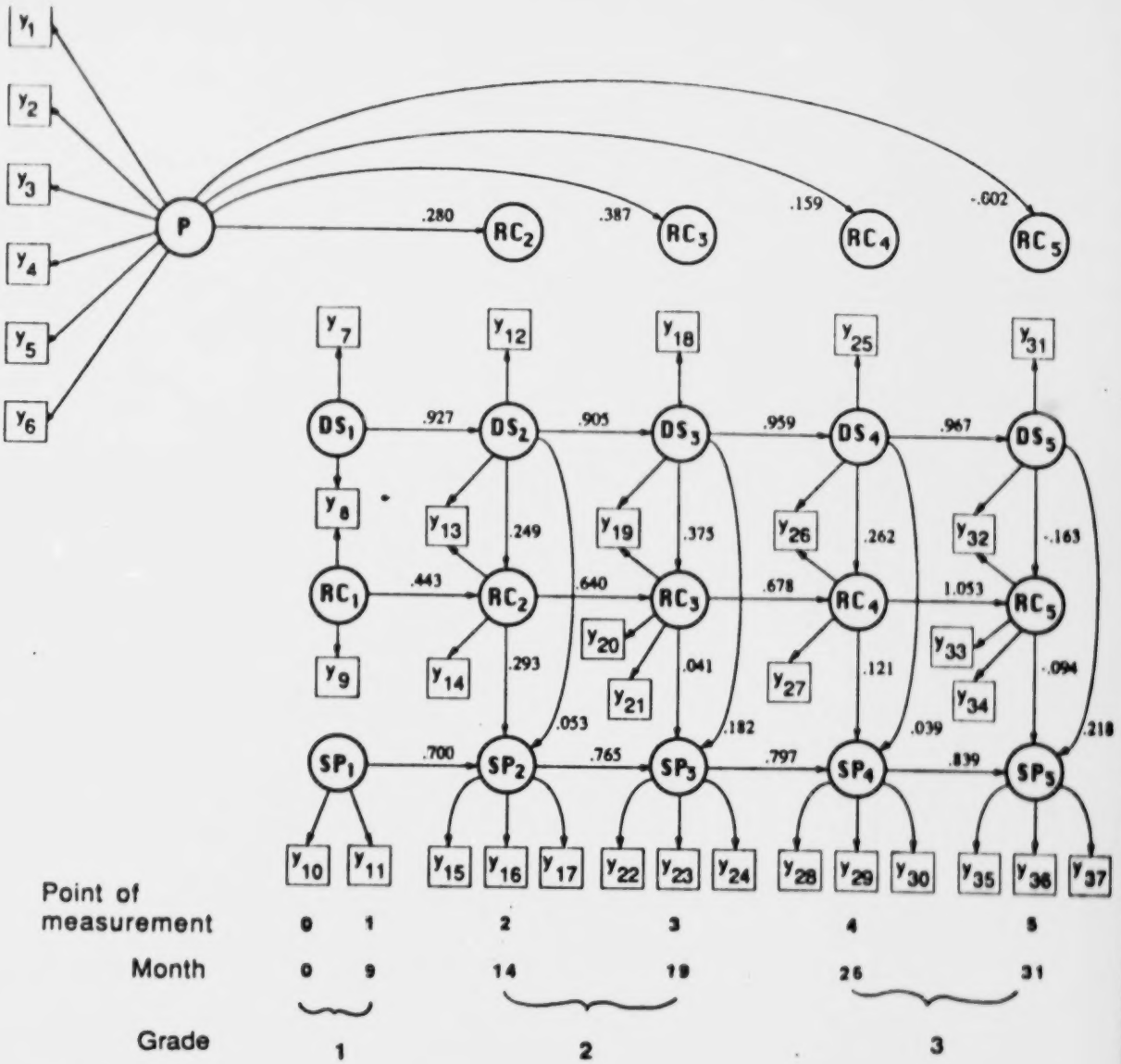

Figure 2

Model with path coefficients resulting from a longitudinal analysis by means of the LISREL program

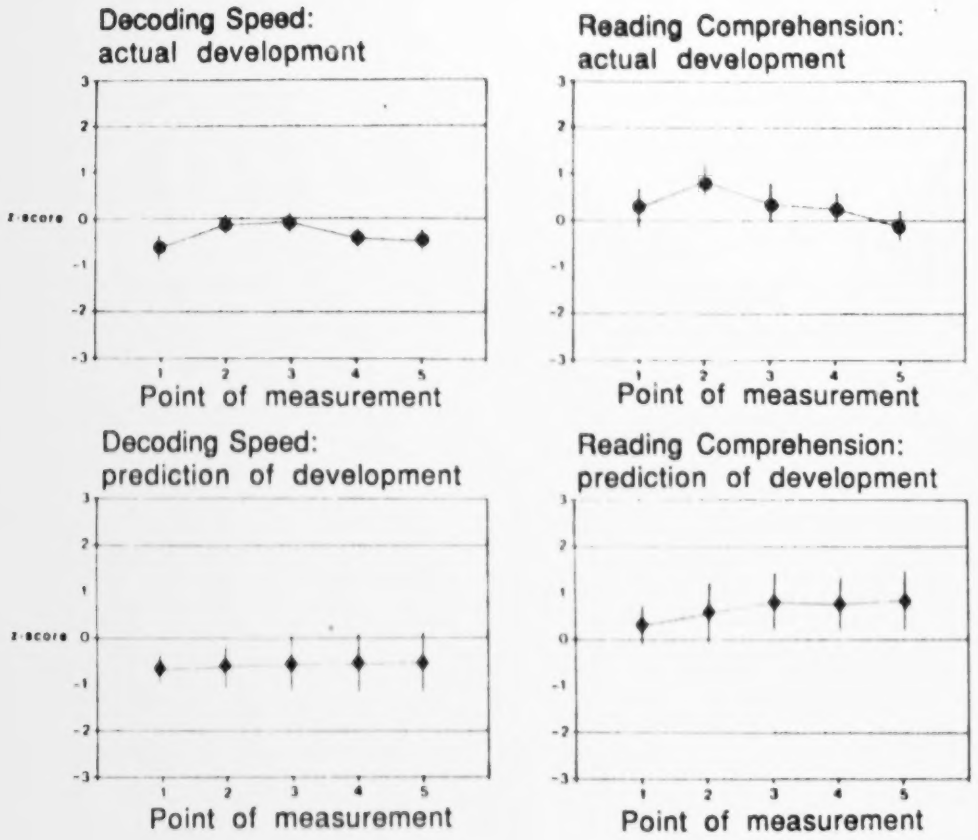
Decoding Speed:
actual development
Reading Comprehension:
actual development
Decoding Speed:
prediction of development
Reading Comprehension:
prediction of development
z-score
Point of measurement
Kalman filter estimates of latent z scores with exception of the first point of measurement which are Bartlett estimates.
Predicted latent z scores on the base of the first point of measurement.
Estimate c.q. prediction ± one standard error

Figure 3

Example of development of Decoding Speed and Spelling with a student from grade 1 through 3